QGP France 2015

Etretat

Quarkonia in pp, p–Pb and Pb–Pb collisions with ALICE

Antoine Lardeux

<u>Outlook:</u>

- ✓ Physics motivations
- ✓ pp collisions
- ✓ p–Pb collisions
- ✓ Pb–Pb collisions

Why study quarkonium productions in heavy ions collisions?

$Q\bar{Q}$ pairs are produced in the initial hard partonic collisions and $\tau_{Q\bar{Q}} > \tau_{\mathrm{QGP}}$

J/ψ suppression is a promising probe of de-confinement [Matzui, Satz, PLB 178 (1986) 416]

↳ Color screening mechanism induced by the high density of color charges in QGP

↳ Sequential suppression

Another mechanism so called Recombinaison can occur:

↳ Statistical recombinaison at phase boundary [Braun-Munzinger, Stachel, PLB 490 (2000) 196]

↳ Dissociation and recombination in QGP describe by a rate equation [Thews et. al., PRC 63 (2001) 054905]

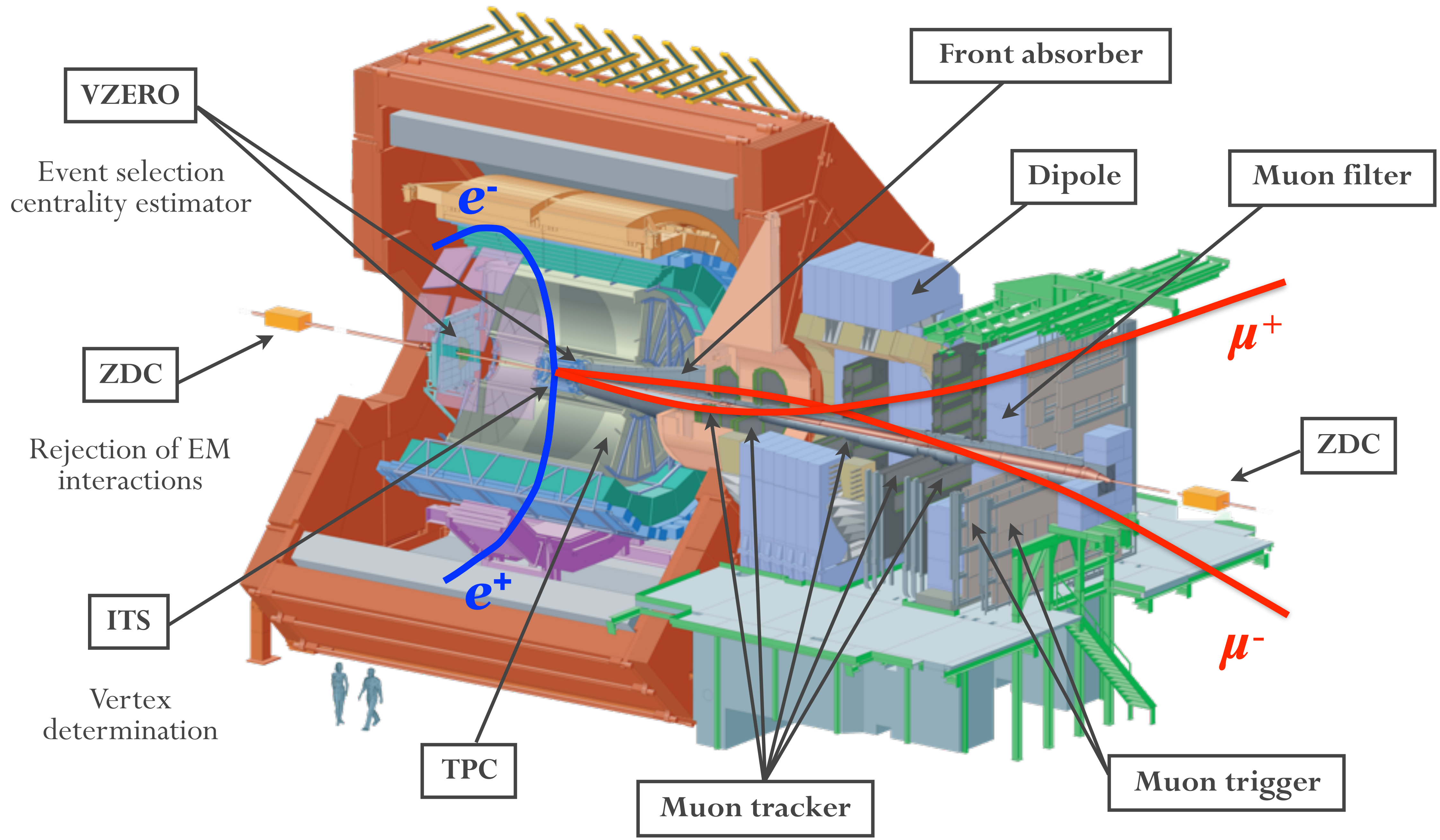
And feed-down from higher states complicate the picture.

Quarkonium states are expected to provide information on de-confinement and the QGP properties

Why study different systems?

- pp
  - Production mechanisms (Color Singlet, Color Octet, Color Evaporation Model)
  - Polarization?
  - **Used as reference** $\longrightarrow$ QGP not expected
- p–A
  - **Cold nuclear matter effects** (modification of PDF, parton energy loss, nuclear break-up, Cronin effect)
  - Initial/final effects?
- A–A
  - **Hot nuclear matter effects** (suppression, recombinaison)
  - Collective effects
  - Thermalization?

ALICE apparatus



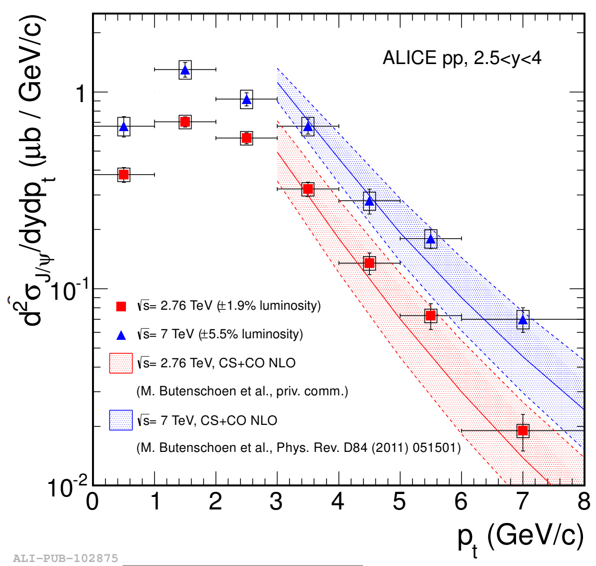
Inclusive quarkonium productions measured down to zero transverse momentum

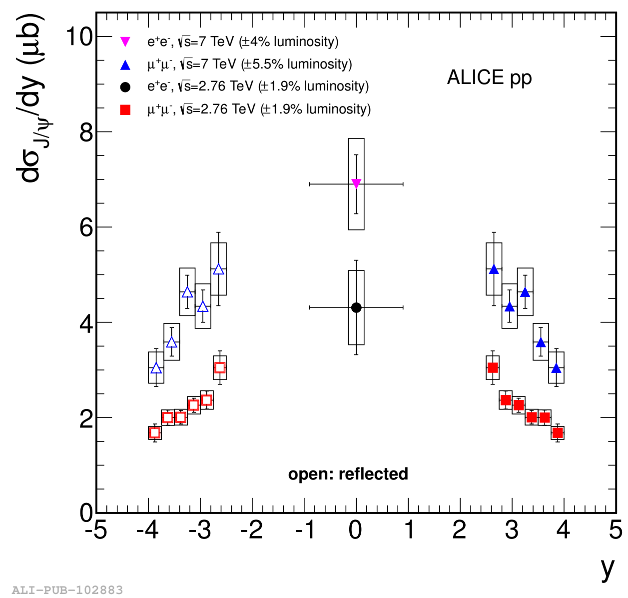
pp collisions

pp collisions

J/ψ cross section

PLB 718 (2012) 295

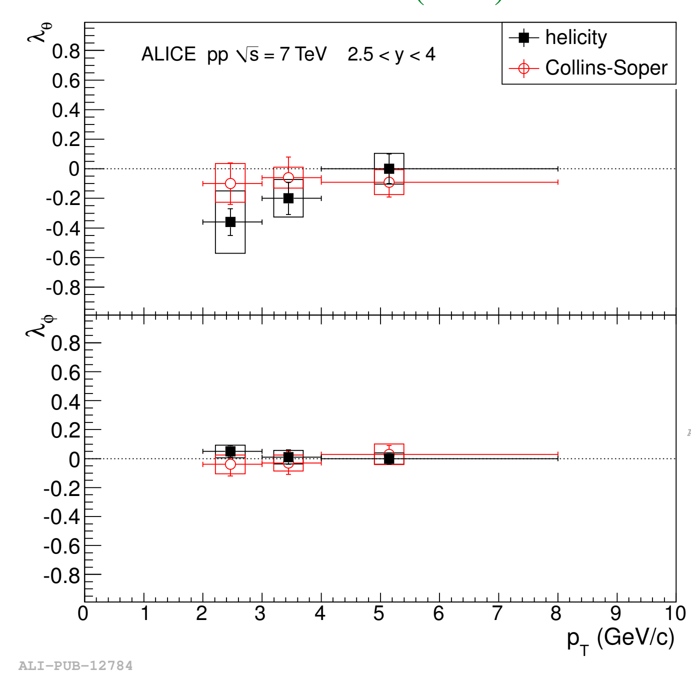


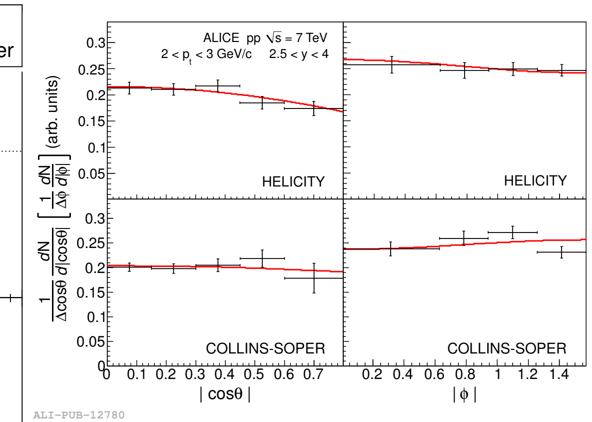


Victor Feuillard 11h00 pp@8TeV

J/ψ polarization

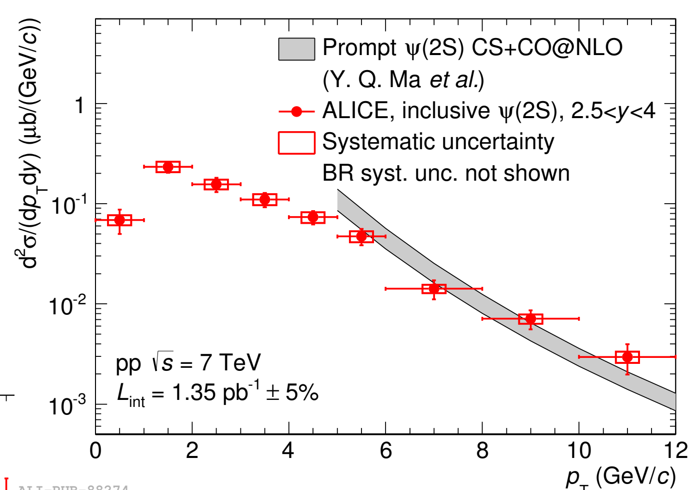
PRL 108 (2012) 082001





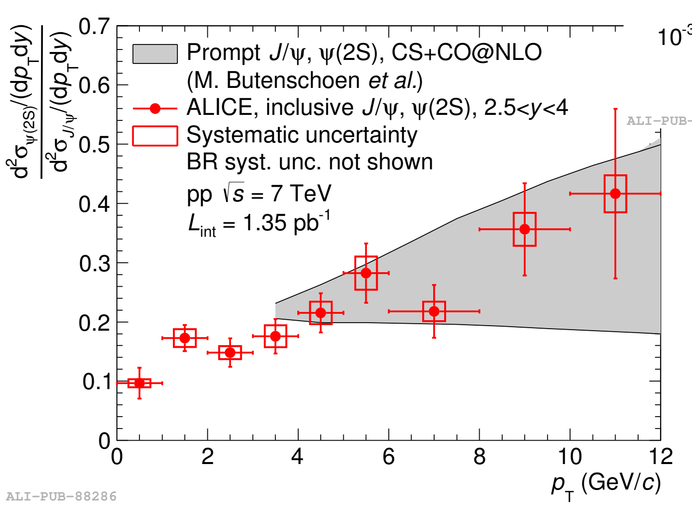
Arianna Batista 11h30 pp@8TeV

$\psi(2S)$ cross section



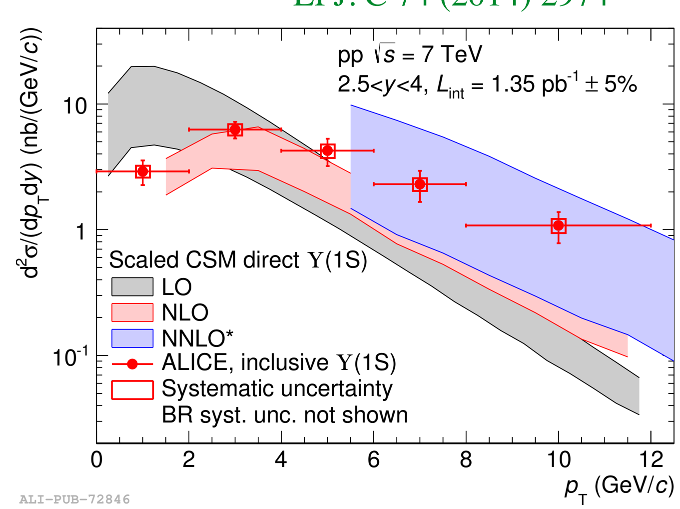
EPJ. C 74 (2014) 2974

ψ ratio

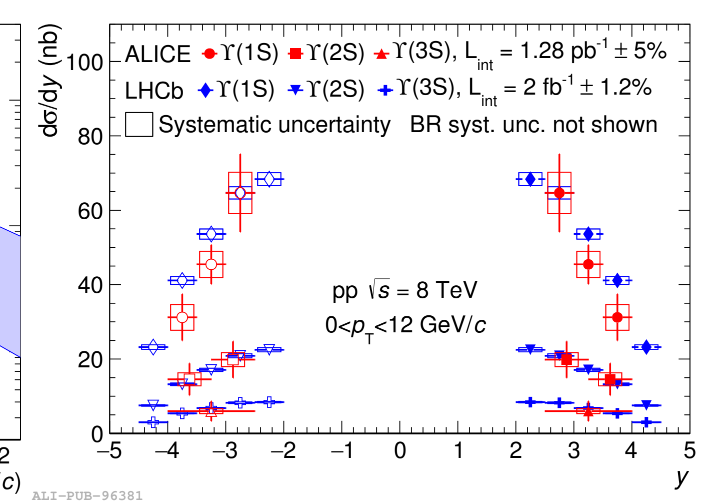


Υ cross sections

EPJ. C 74 (2014) 2974



arXiv:1509.08258



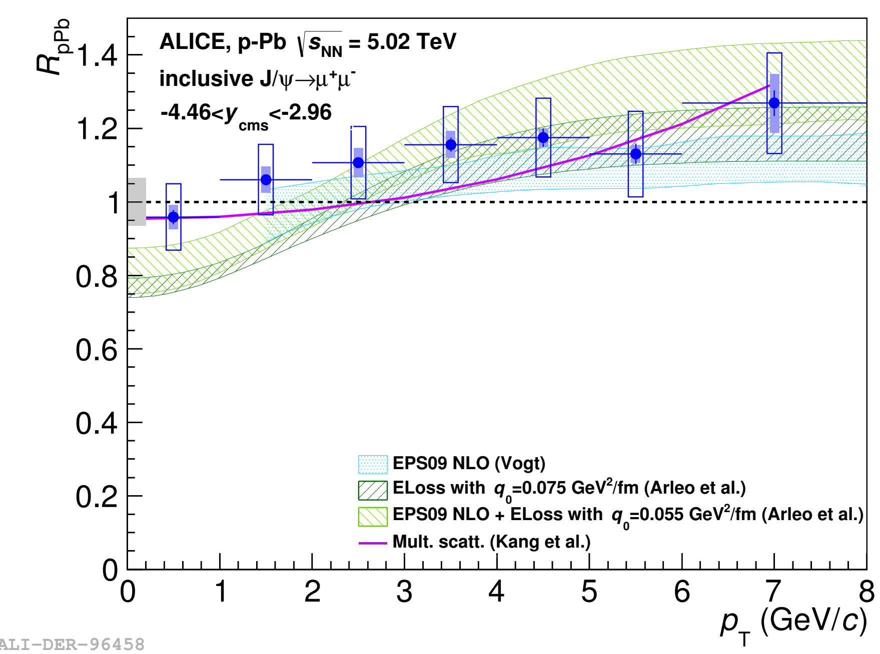
p–Pb collisions

Usual observable is the nuclear modification factor:

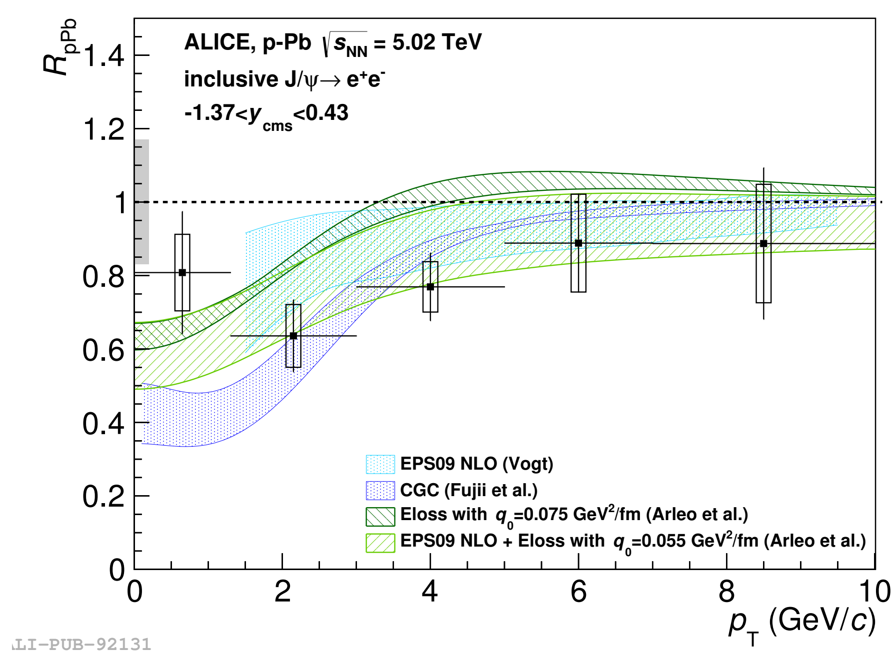
$$R_{\mathrm{pA}} = \frac{Y_{\mathrm{pA}}}{N_{\mathrm{coll}}\, Y_{\mathrm{pp}}}$$

nuclear modification factor vs transverse momentum

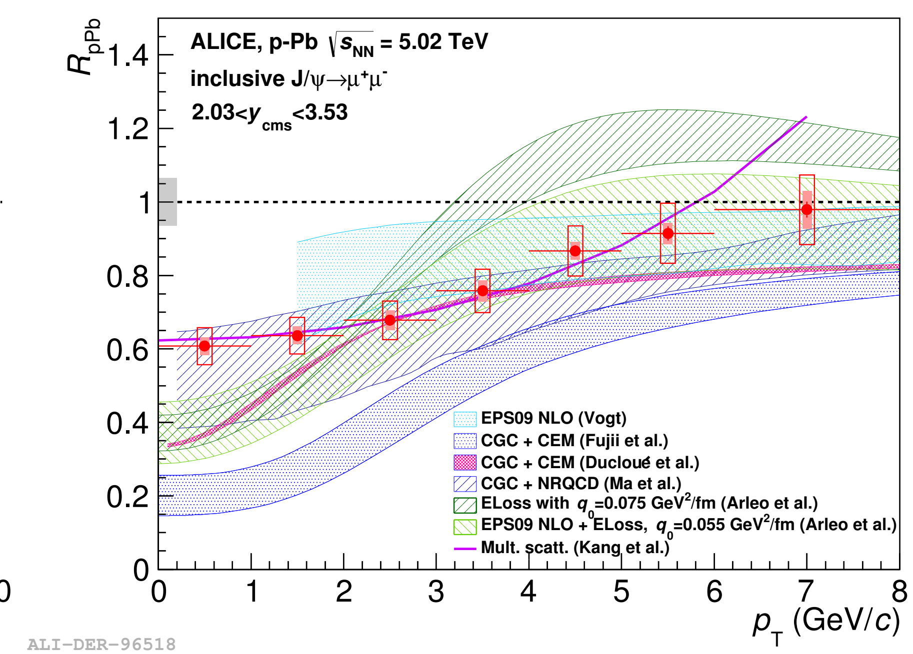
[JHEP 1506 (2015) 055]



Backward-*y* ($J/\psi \to \mu^+\mu^-$)



Mid-*y* ($J/\psi \to e^+e^-$)



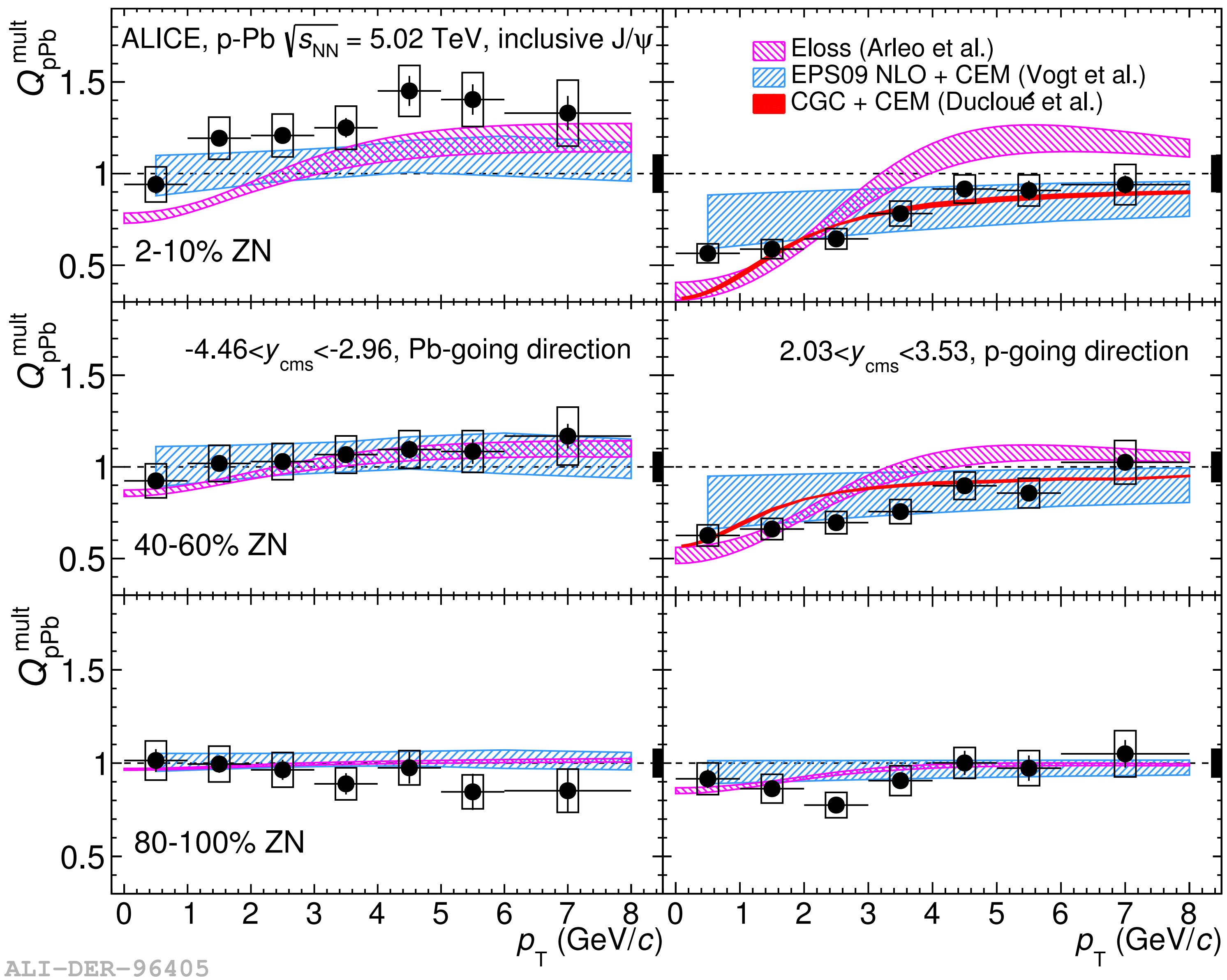
Forward-*y* ($J/\psi \to \mu^+\mu^-$)

no significant nuclear effects

suppression at low p_T ($p_T < 5$ GeV/c)

nuclear modification factor vs p_T for different centrality classes

[arXiv:1506.08808]



Backward-y ($J/\psi \to \mu^+\mu^-$) **Forward-y ($J/\psi \to \mu^+\mu^-$)**

Central collisions:

backward-y: hint of a Q_{pPb} increase for $p_T > 1$ GeV/c

Forward-y: J/ψ is suppressed at low p_T ($p_T < 5$GeV/c)

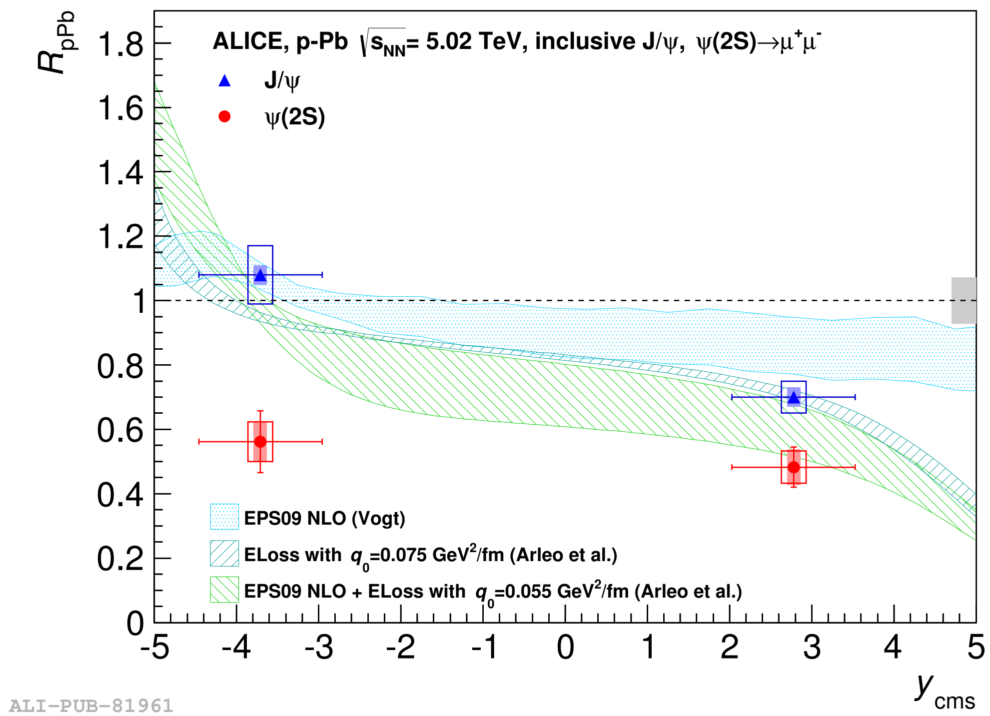
Peripheral collisions:

J/ψ Q_{pPb} is compatible with unity in the full p_T interval

Caveat: Q_{pPb} instead of R_{pPb} due to possible biases on $<T_{pPb}>$

$\psi(2S)$

[JHEP 1412 (2014) 073]

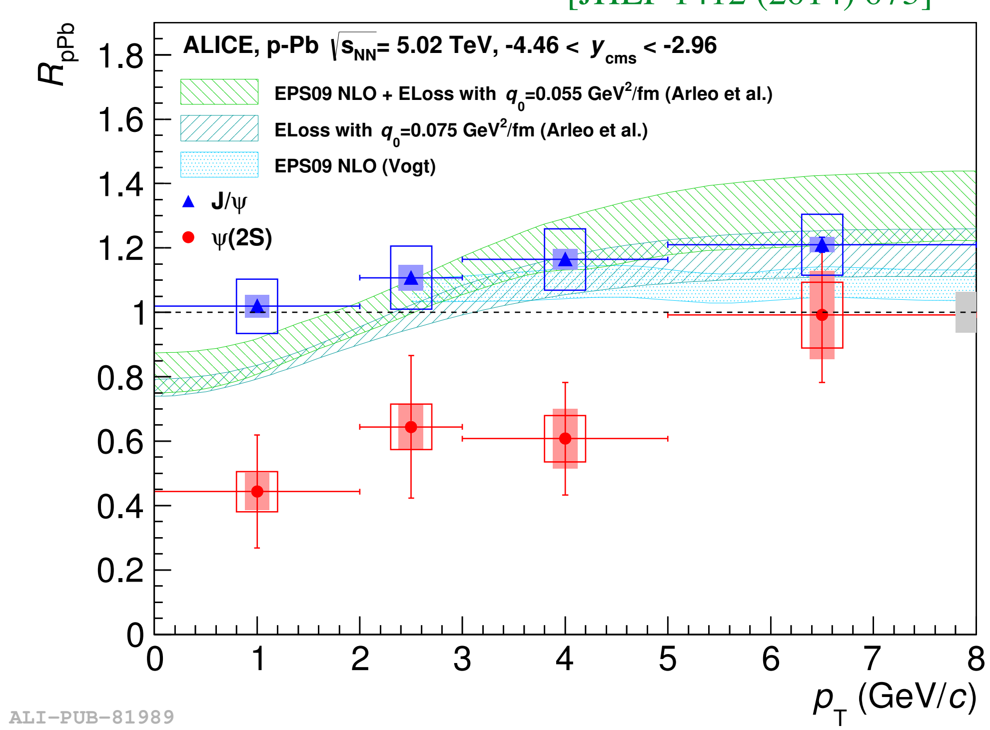


ψ(2S) is more suppressed than the J/ψ at both backward and forward rapidities

Shadowing and energy loss cannot describe the larger ψ(2S) suppression compared to the J/ψ

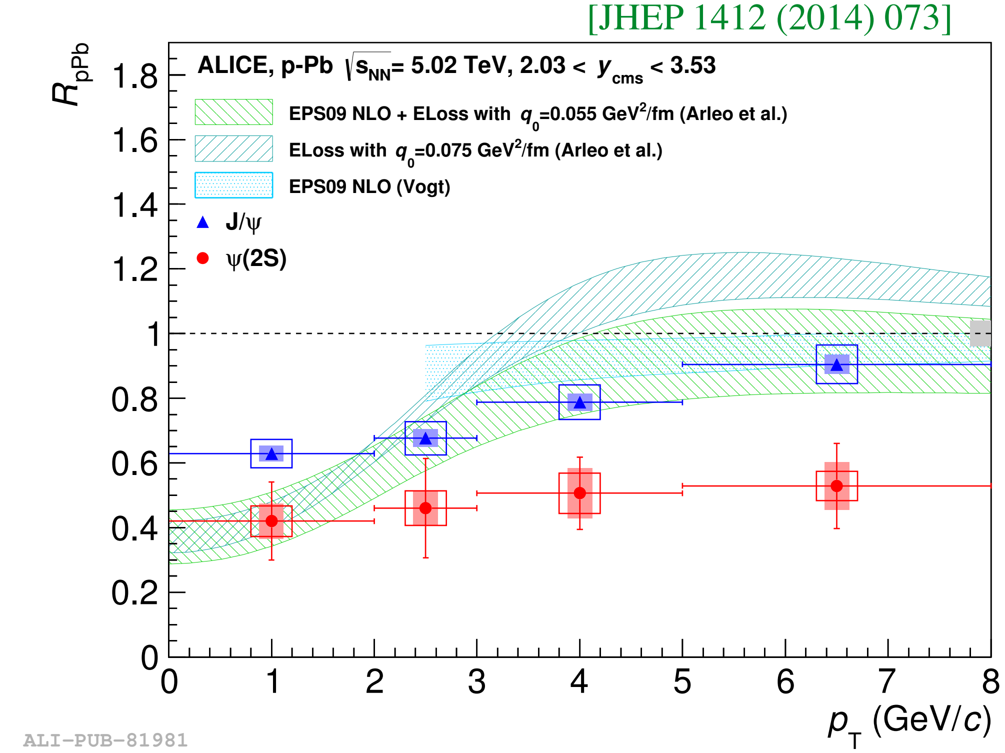
Additional mechanism is needed

[JHEP 1412 (2014) 073]



Backward-*y* (J/ψ→ μ⁺μ⁻)

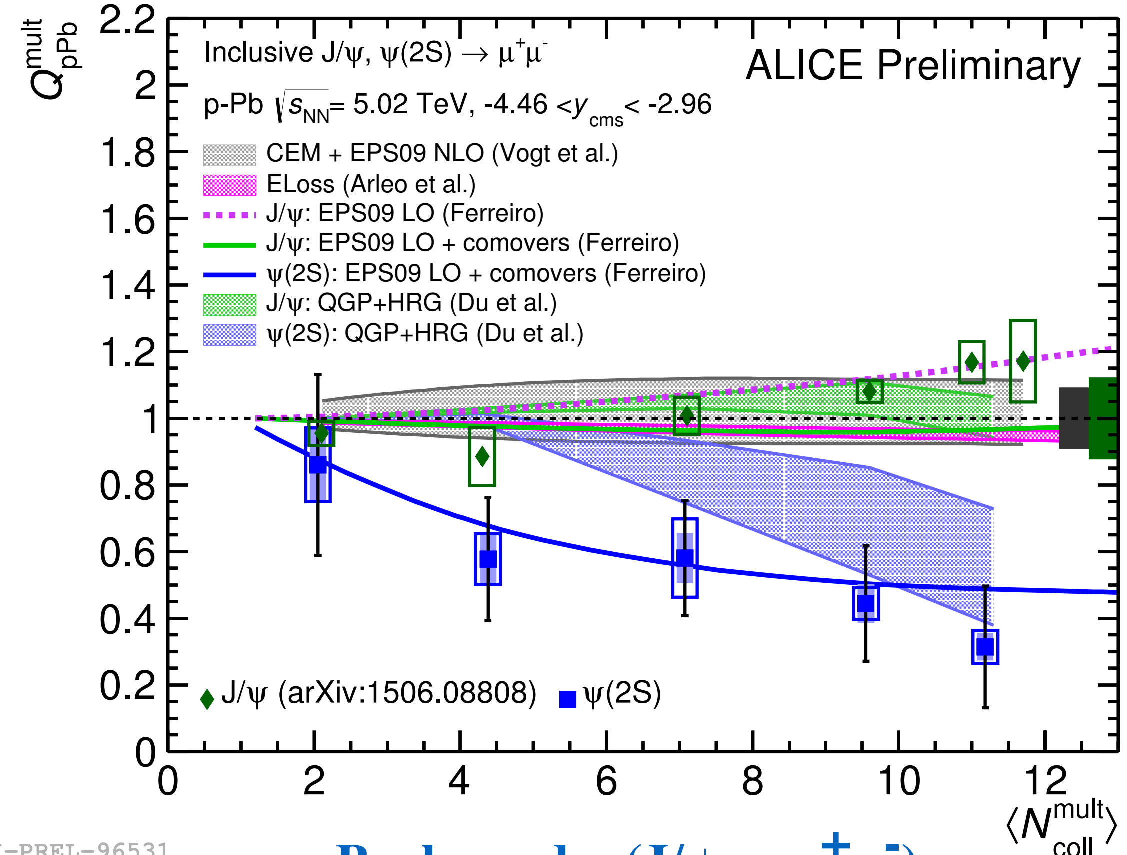
[JHEP 1412 (2014) 073]



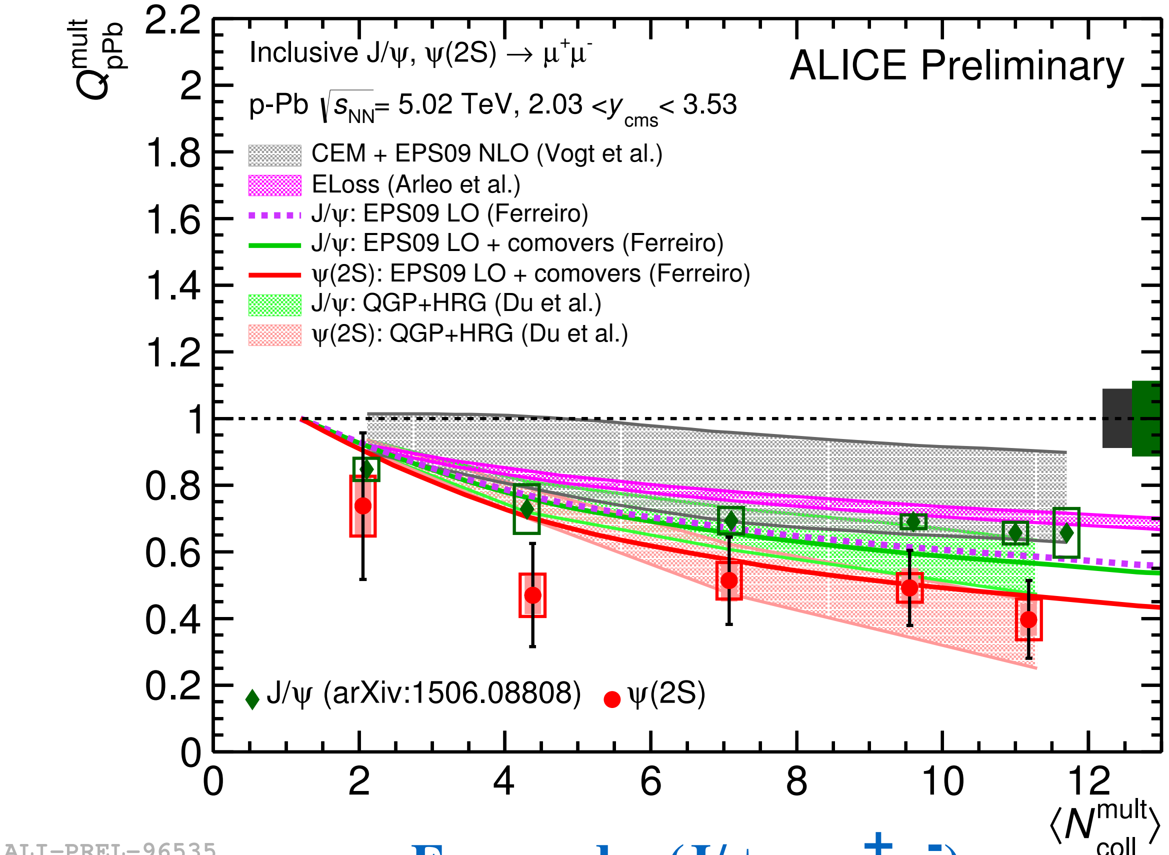
Forward-*y* (J/ψ→ μ⁺μ⁻)

$\psi(2S)$

nuclear modification factor vs collision centrality



Backward-y (J/ψ→ μ+μ-)



Forward-y (J/ψ→ μ+μ-)

$\psi(2S)$ suppression increase as a function of centrality

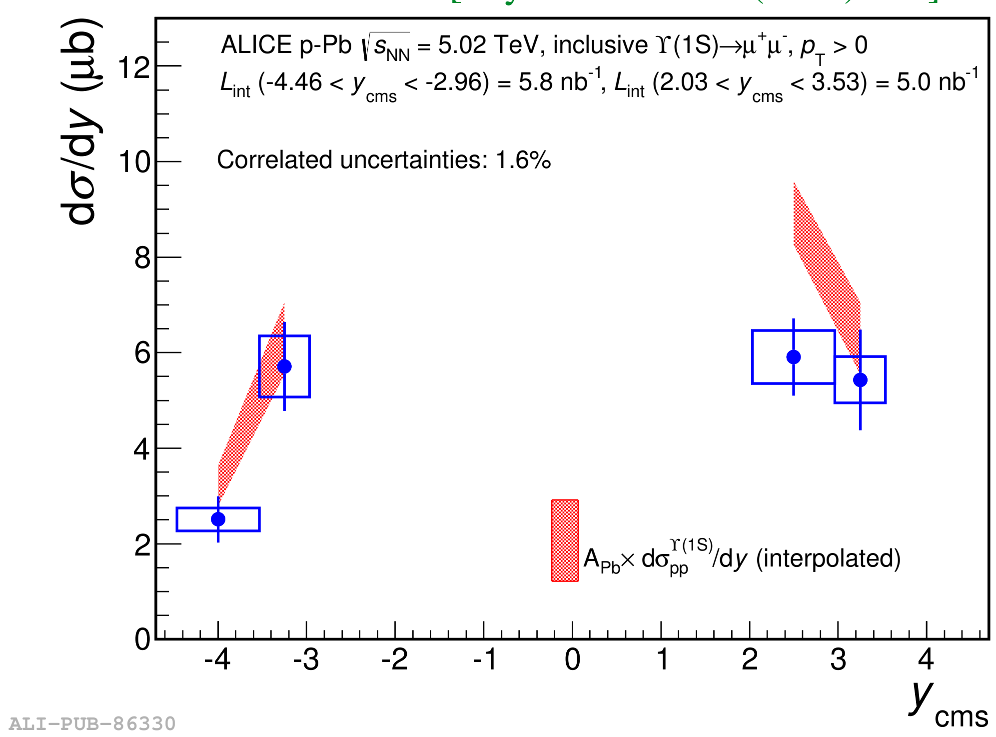
Indications for smaller $\psi(2S)$ Q_{pPb} compared to the J/ψ

Theoretical models based only on shadowing and energy loss in disagreement with $\psi(2S)$ data

Interaction with comovers represent a possible explanation for the larger $\psi(2S)$ suppression

QGP + Hadron Resonance Gas model in fair agreement with data

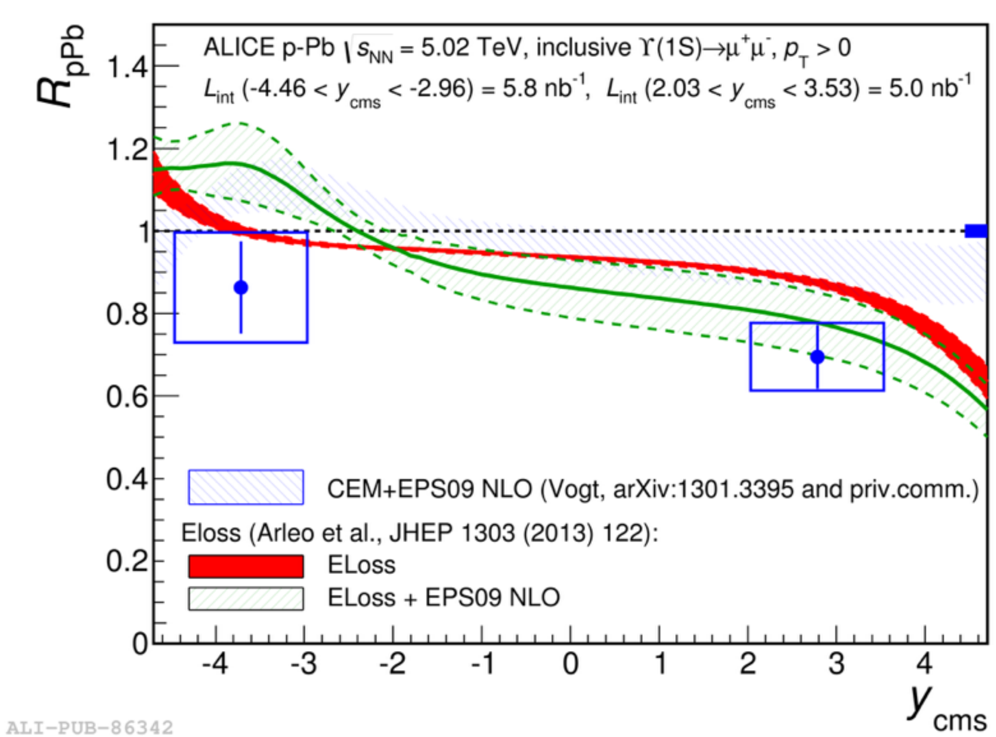
[Phys. Lett. B 740 (2015) 105]

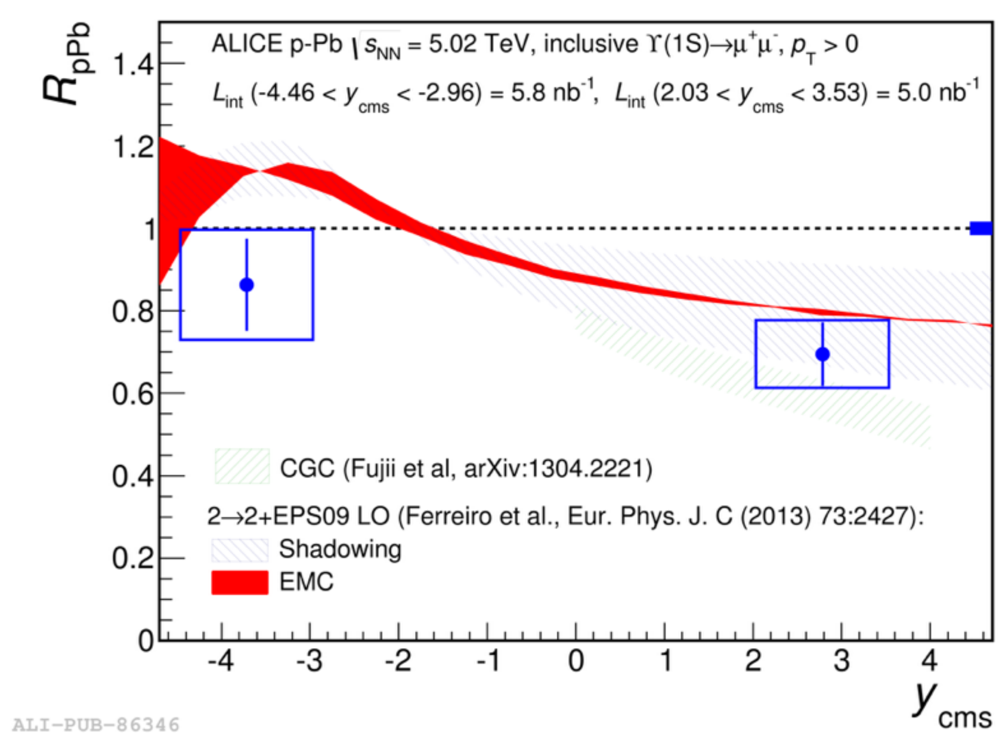


forward-y: Suppression with respect to A_{Pb}-scaled pp reference,

backward-y: compatible with no suppression.

Model underestimates the $\Upsilon(1S)$ suppression at backward rapidity

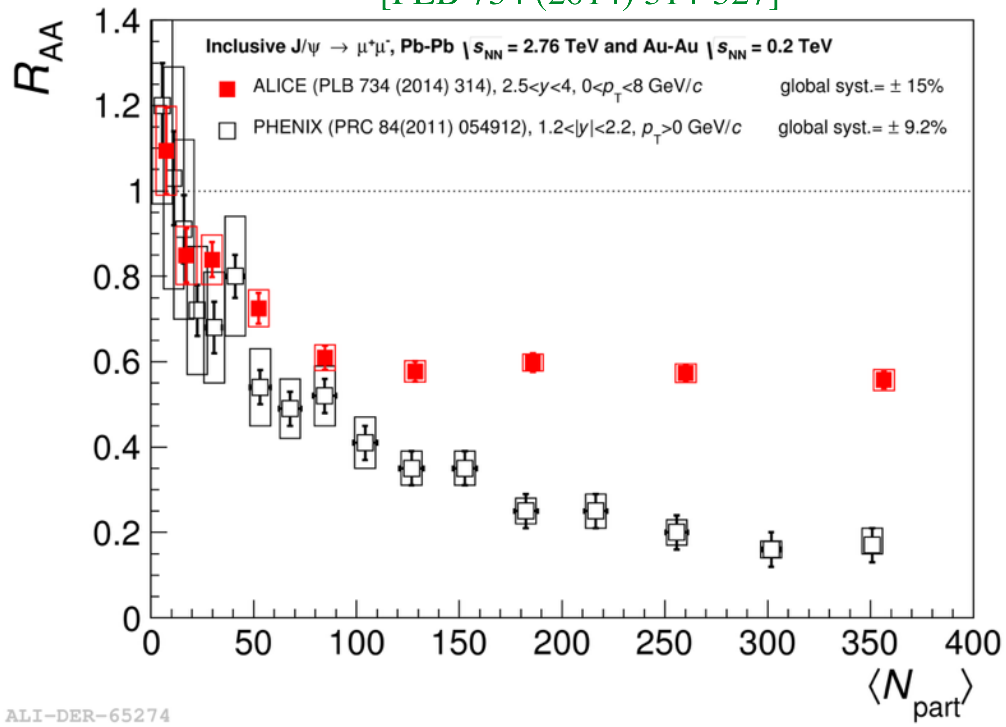




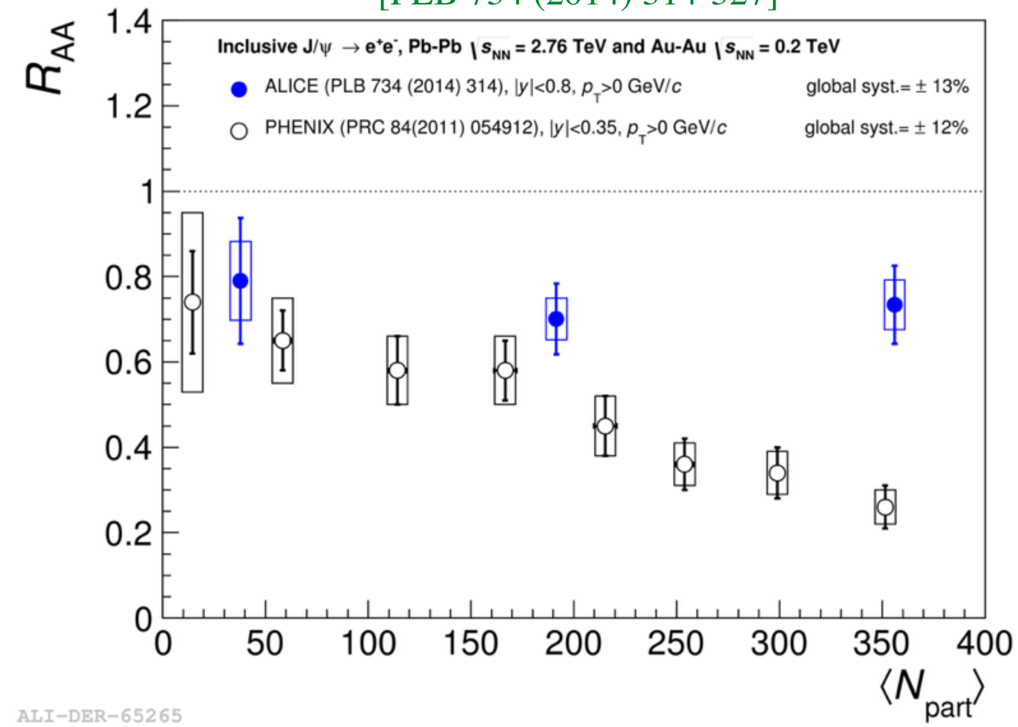
Pb–Pb collisions

Nuclear modification factor as a function of collision centrality

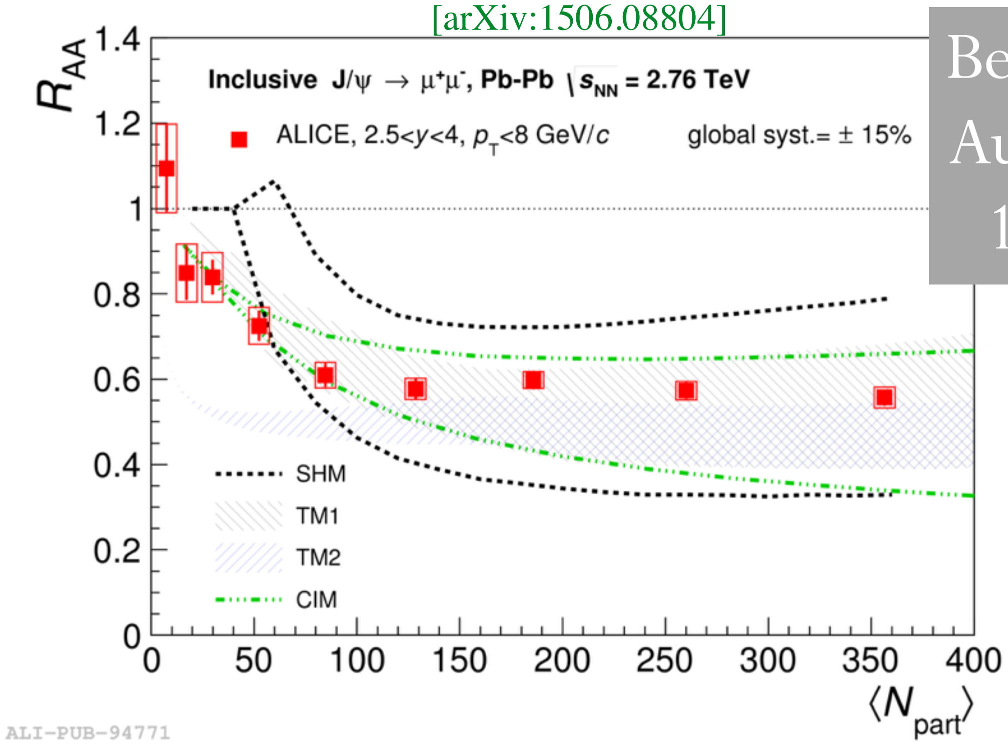
[PLB 734 (2014) 314-327]



[PLB 734 (2014) 314-327]

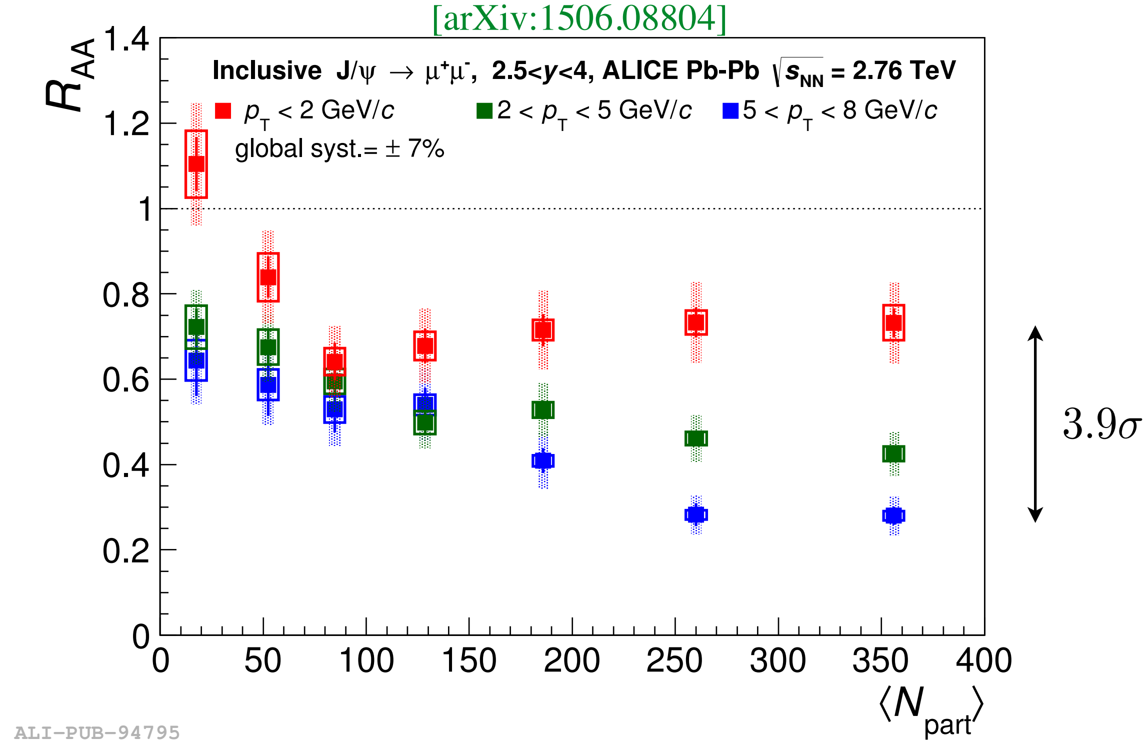


[arXiv:1506.08804]

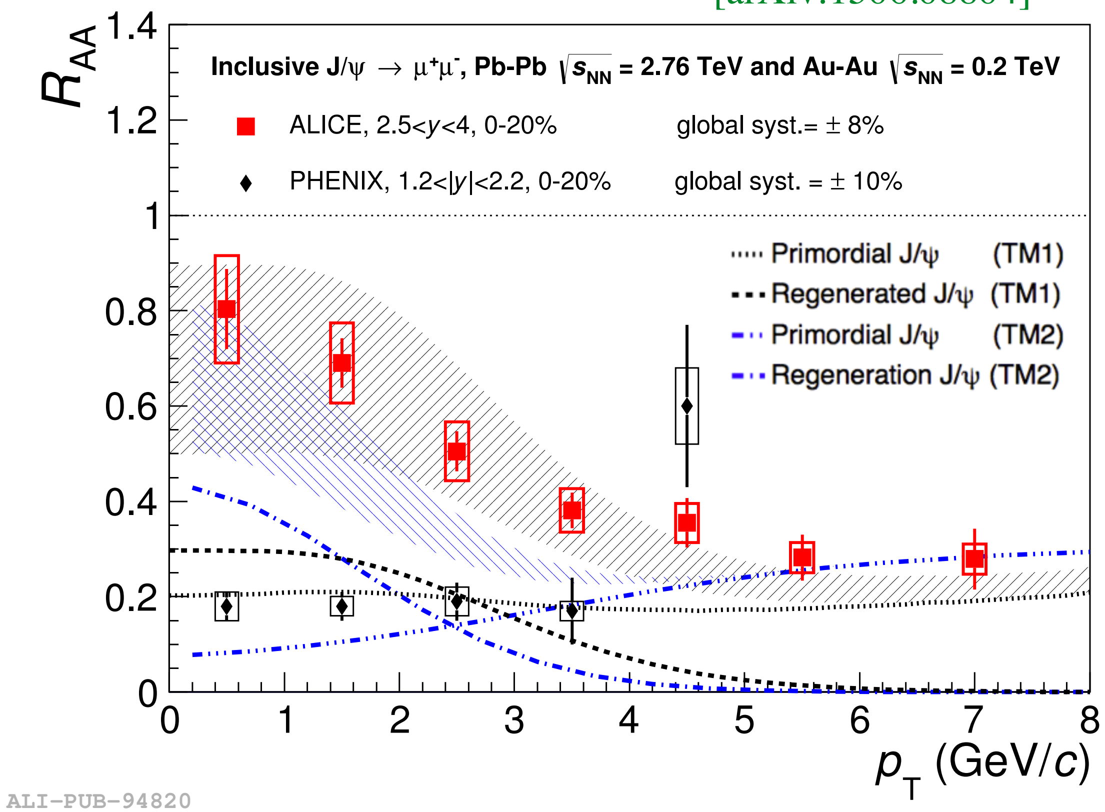


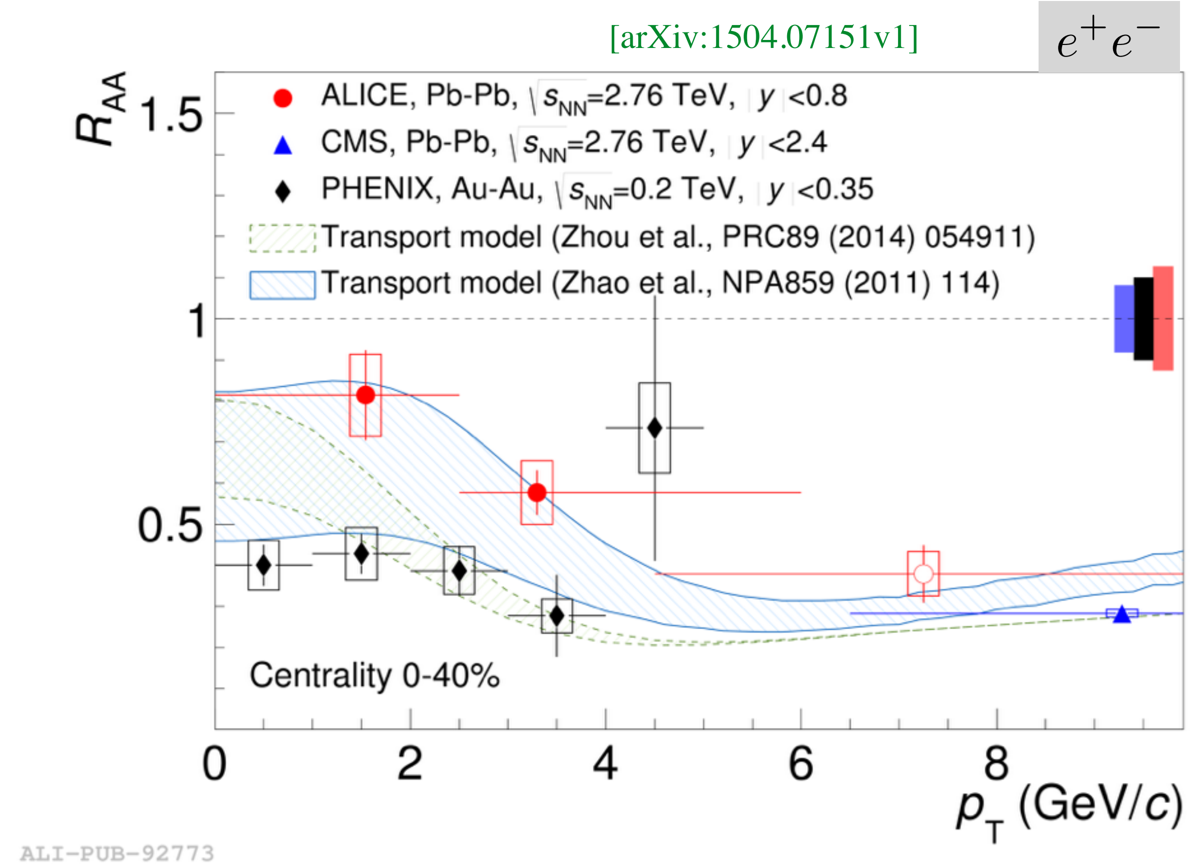
Benjamin Audurier 12h00

[arXiv:1506.08804]



Nuclear modification factor as a function of transverse momentum





R_{AA} at low p_{T} is almost 4 times larger than the one at PHENIX.

Decrease of R_{AA} with increasing p_{T}

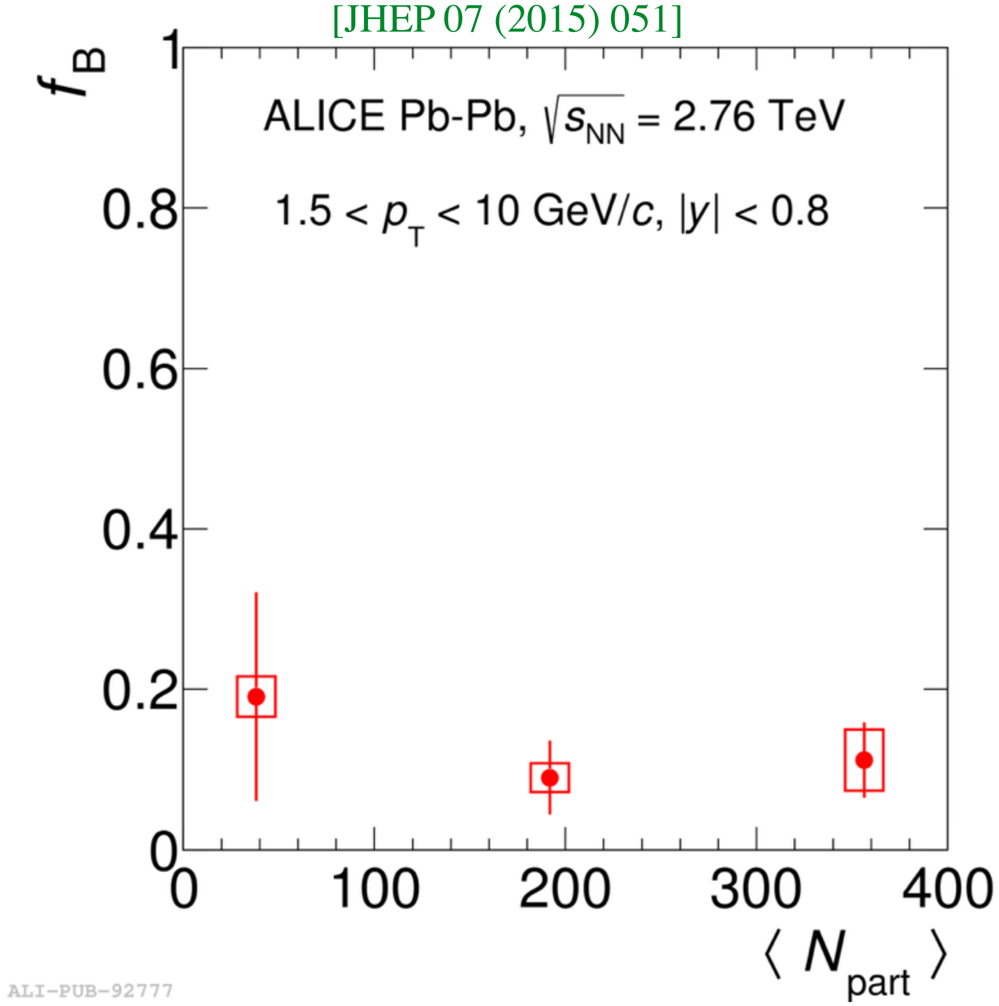
This behavior is expected by all the models which include regeneration mechanism (concentrate at low p_{T})

In clear contrast to the p_{T} dependence measured at lower energy by PHENIX

Prompt and non-prompt separation at mid-rapidity

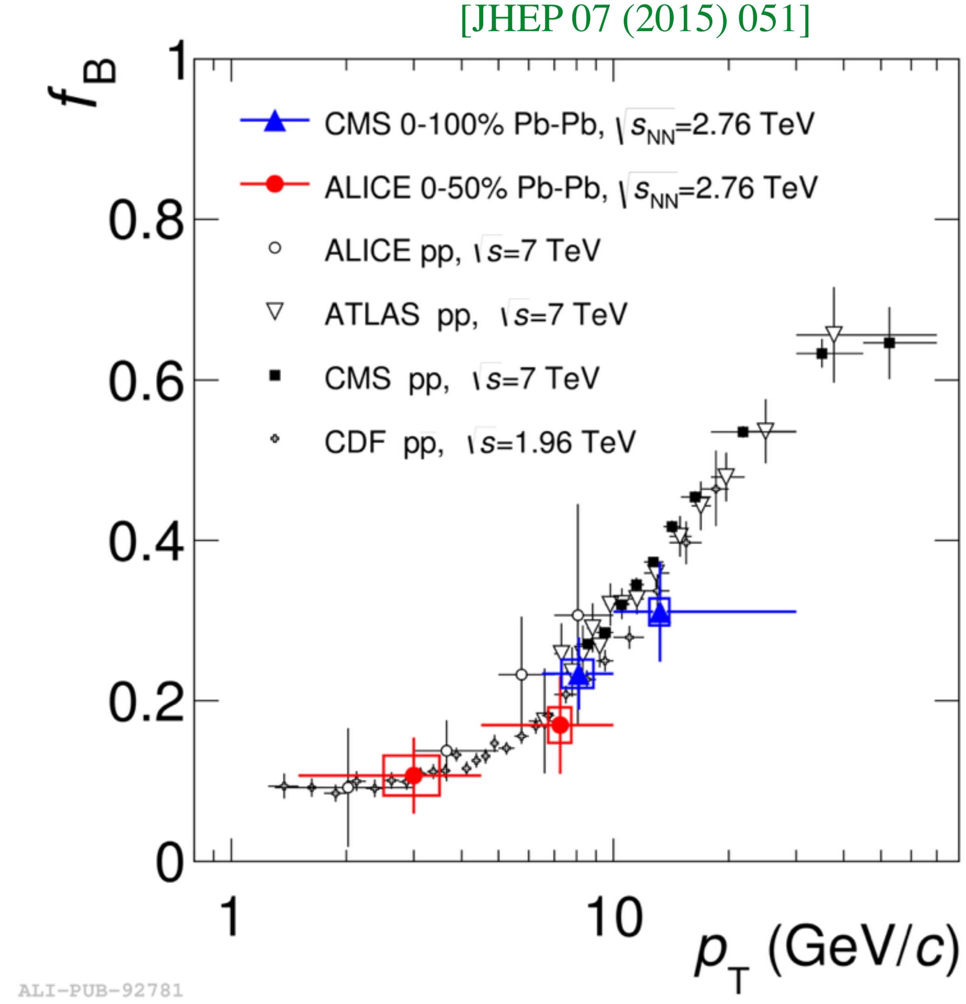
f_B = non-prompt / inclusive

[JHEP 07 (2015) 051]



Compatible with no centrality dependence

[JHEP 07 (2015) 051]

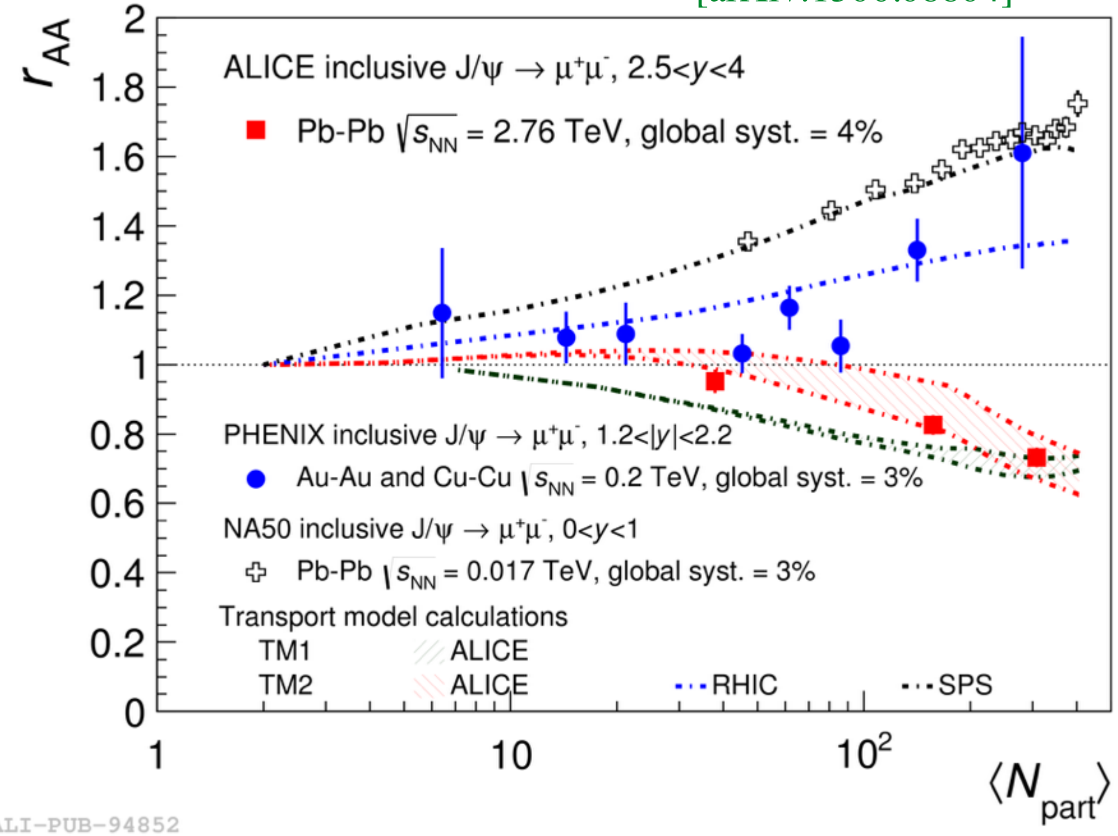


Similar in pp and Pb-Pb

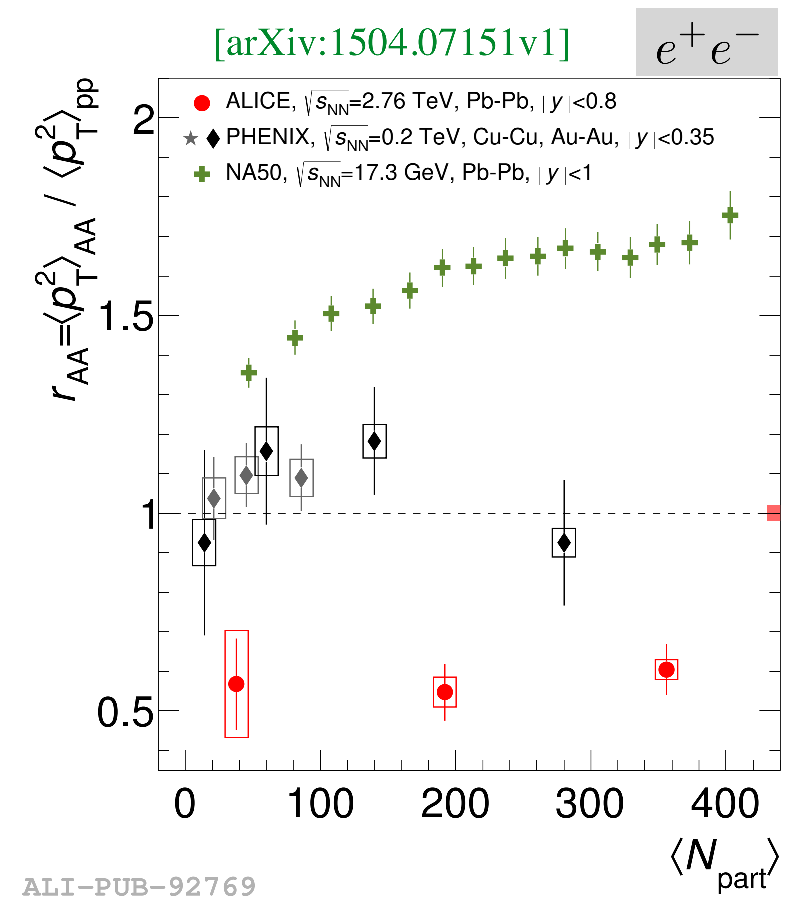
$$R_{AA}^{inclusive} = R_{AA}^{prompt}$$

$$r_{\mathrm{AA}} = \frac{\langle p_{\mathrm{T}}^2 \rangle_{\mathrm{AA}}}{\langle p_{\mathrm{T}}^2 \rangle_{\mathrm{pp}}} \quad \longrightarrow \quad \text{Sensitive to medium modifications of } J/\psi \; p_{\mathrm{T}}$$

[arXiv:1506.08804]



[arXiv:1504.07151v1]



Significantly below unity

Opposite trend compare to SPS energy

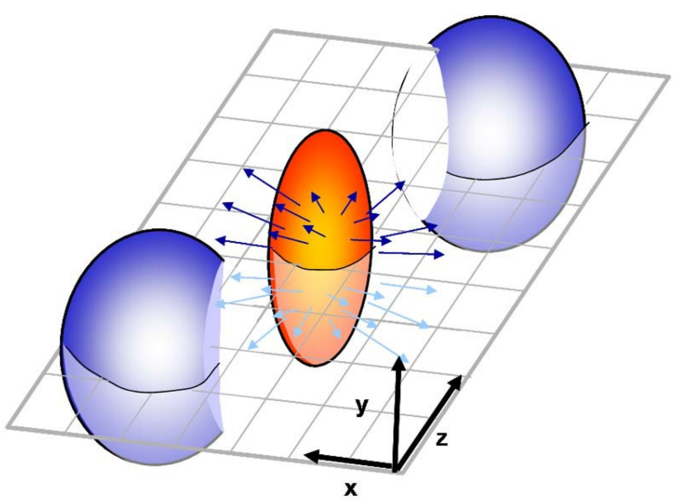
Transport models are able to reproduce the data from the different energies

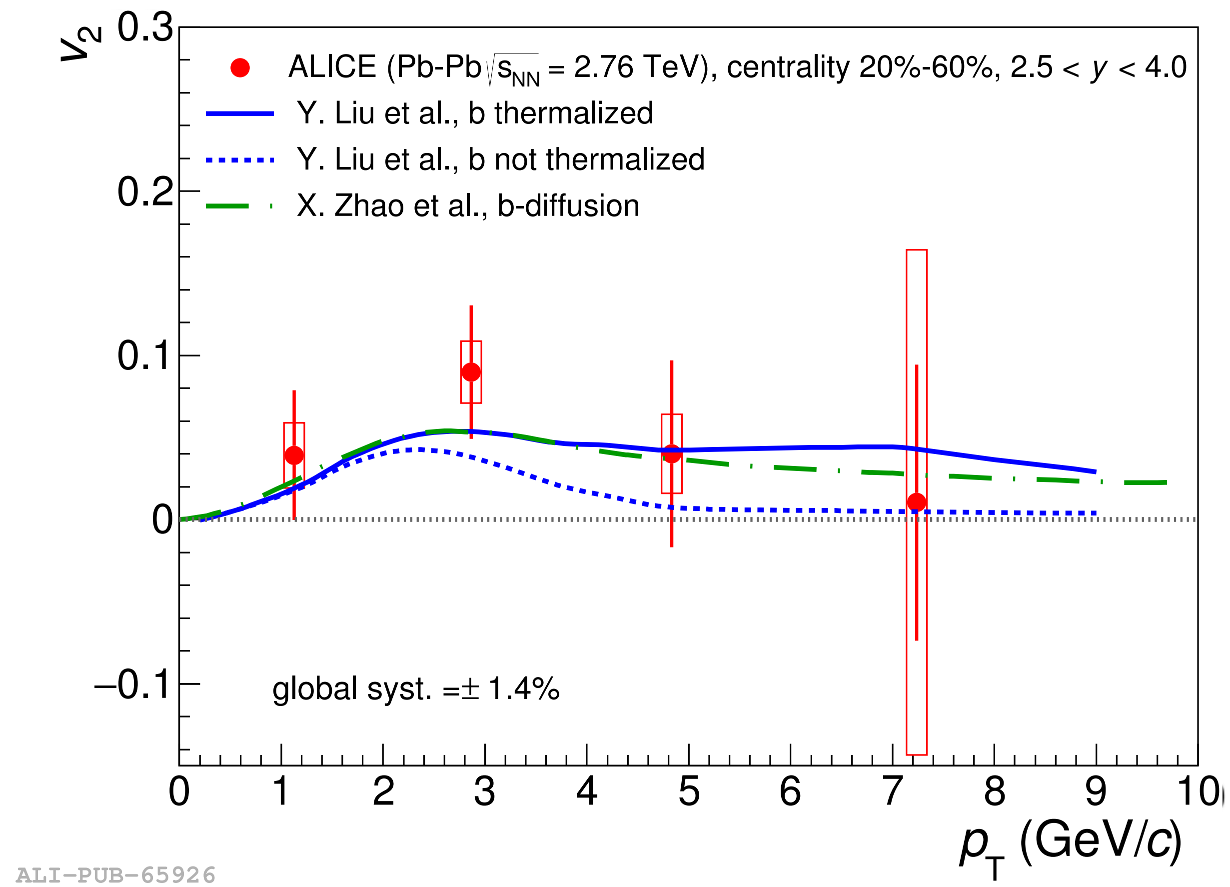
Could be related to the onset of regeneration mechanism and to the thermalization of charm quarks

Flow elliptic

Does the J/ψ inherit any of the fireball collective flow via regeneration?

$$\frac{dN}{d\phi} = N\left(1 + 2v_2 \cos 2(\phi - \psi)\right)$$



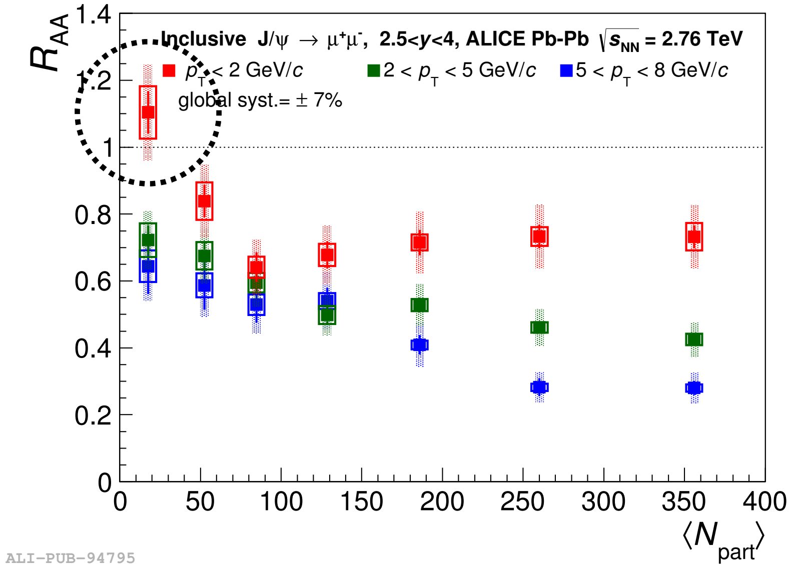


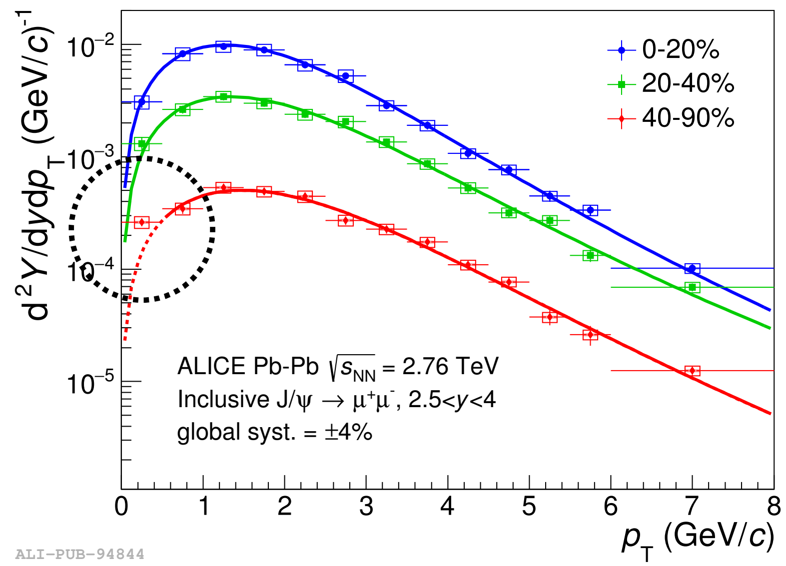
Hint of non-zero J/ψ v_2 (2.7σ)

In agreement with regeneration mechanism

Observation of low p_T excess

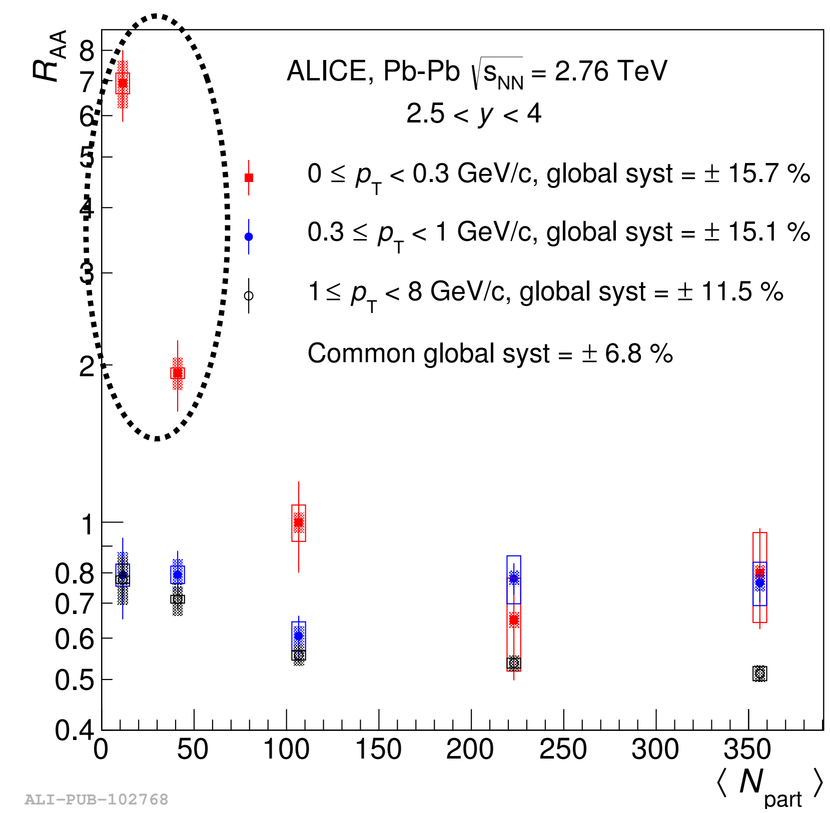
[arXiv:1506.08804]

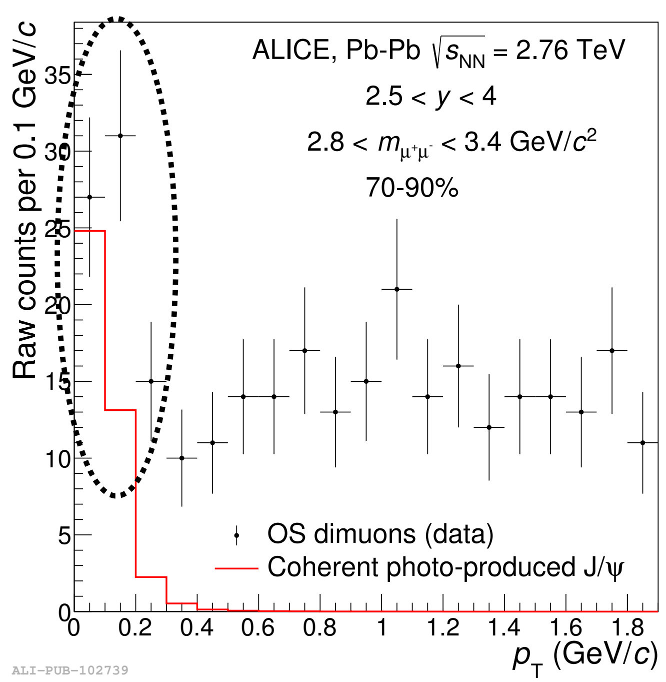




Gines Martinez 16h30

Nuclear modification factor

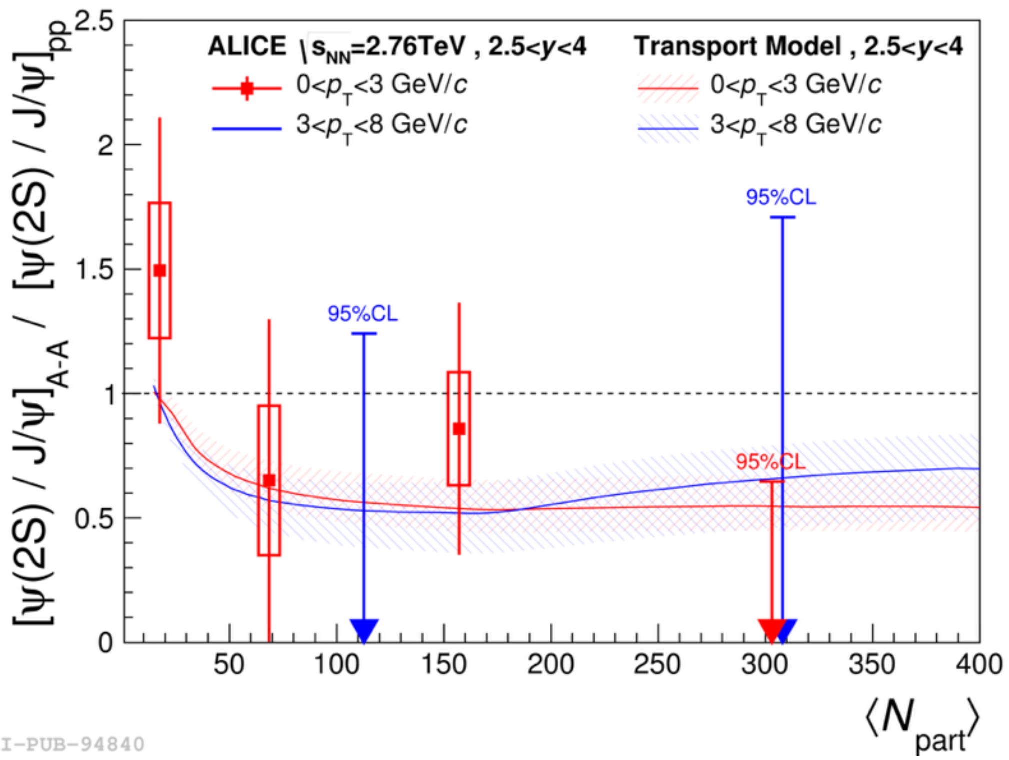




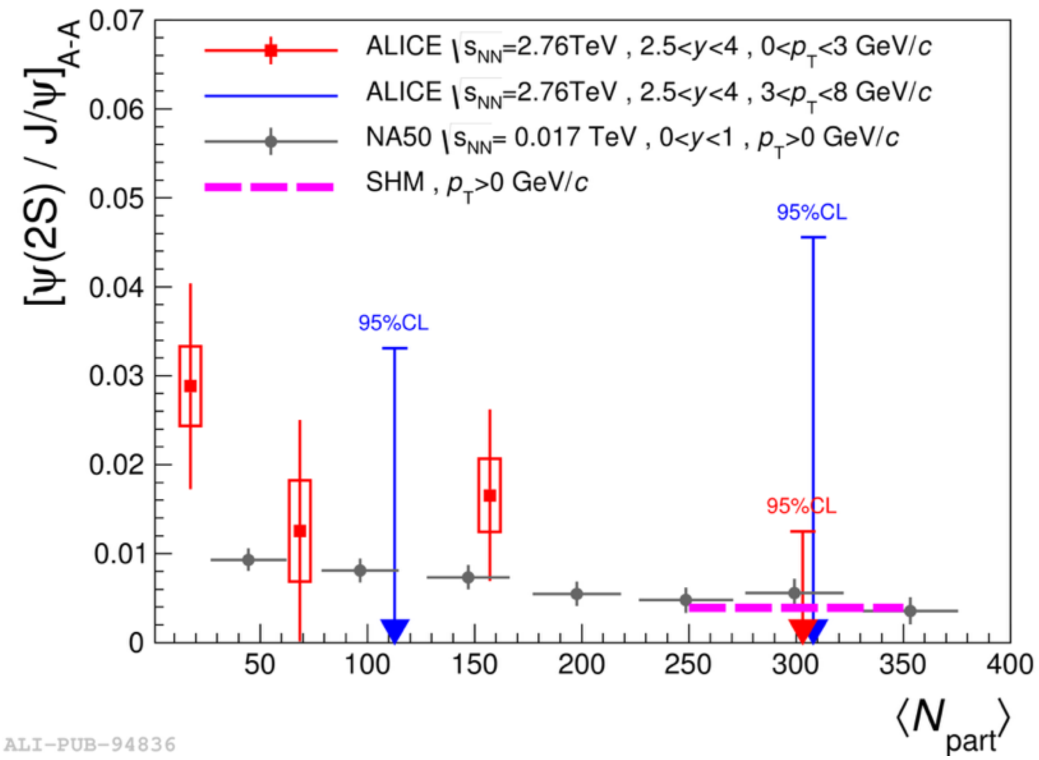
p_T distribution of opposite sign dimuon in invariant mass range $2.8 < m_{\mu\mu} < 3.4$ GeV/c^2

Clear excess visible in most peripheral collisions

Discriminate between Statistical and Transport models



SHM: Andronic et. al., PLB678 (2009) 350-354



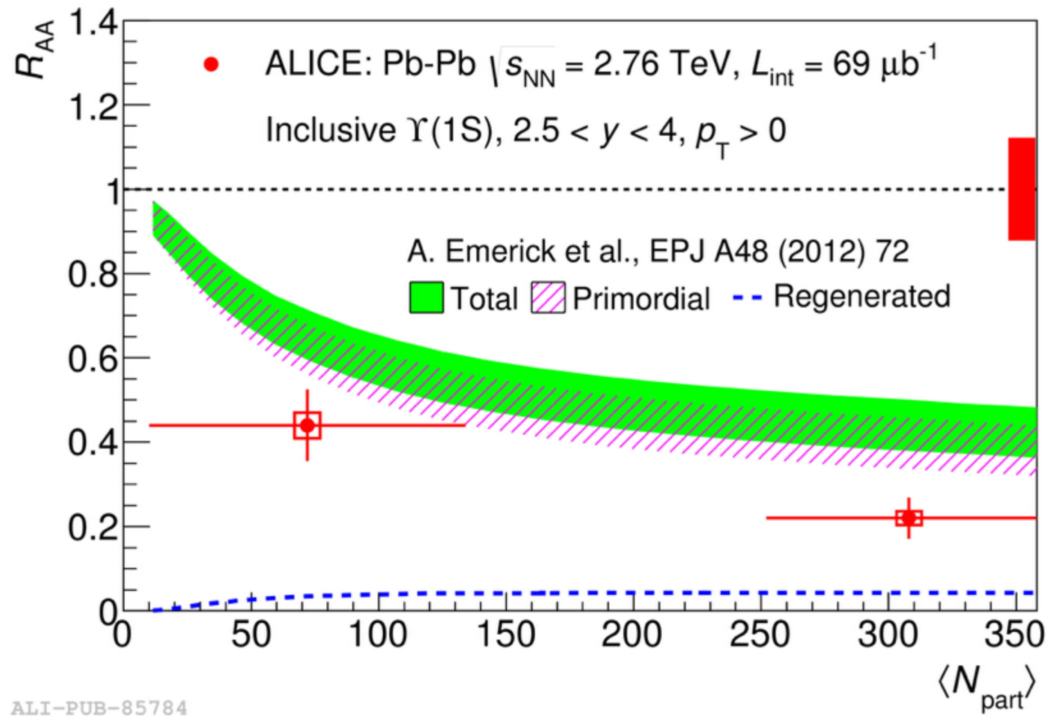
Transport Model: Chen et. al., PLB726 (2013) 725-728

Statistics being limited, statistical and transport models are compatible with the 95% C.L. available for central collisions.

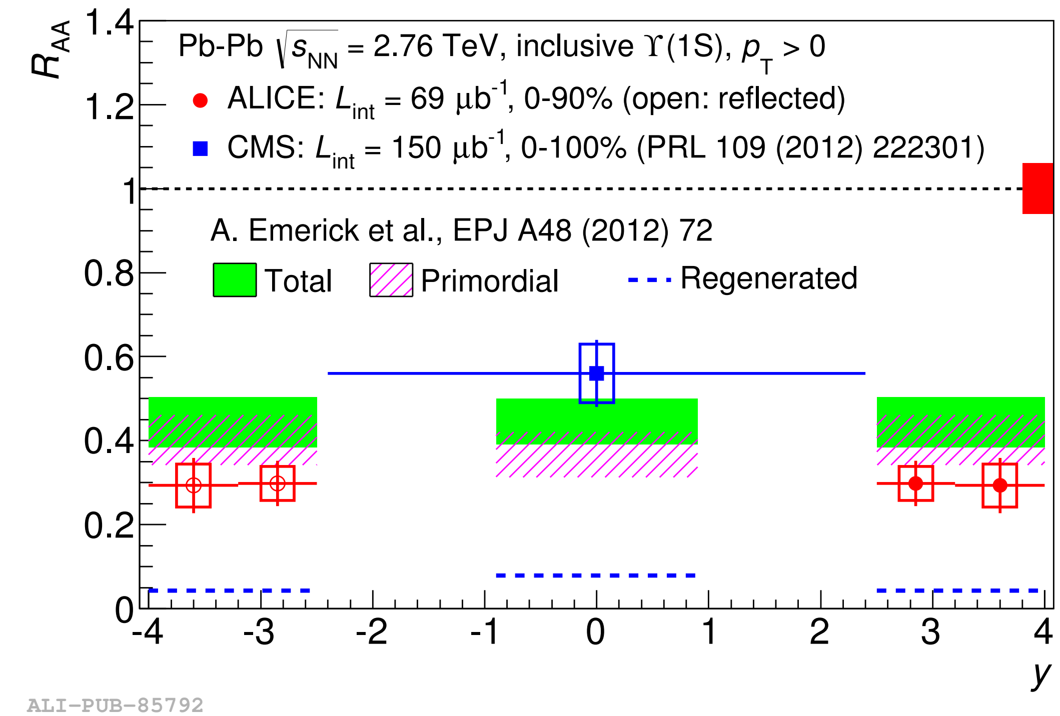
Υ(1S)

Higher mass (more perturbative processus); Less recombinaison than J/ψ; $\Upsilon(1S)$ feed-down between 40-50%.

[PLB 738 (2014) 361–372]



[PLB 738 (2014) 361–372]



Clear $\Upsilon(1S)$ suppression, increasing from semi-peripheral to central Pb-Pb collisions.

The transport model underestimates the observed suppression but reproduce the centrality dependence.

The transport model underestimates the higher suppression observed at forward rapidity.

Need precise measurement of feed down and CNM effects
More data! Wait LHC run-2 (soon)

Conclusion

- pp, p-Pb and Pb-Pb data from run-1 at LHC have been analyze in detail at quarkonia production level.
- Production mechanisms in pp collisions are still not fully understood
- p-Pb results are in agreement with models except for $\psi(2S)$ $\longrightarrow$ final effect?
- Other mechanisms compensating the J/ψ suppression are needed to explain the ALICE J/ψ R_{AA} measurements (regeneration?).
- First observation of very low p_T J/ψ excess in peripheral Pb-Pb collisions.

Outlooks:

More statistic and higher luminosity coming soon with LHC run-2:

- Reduce uncertainties of current measurements.
- Detailed results for bottomonia.
- Study the low p_T J/ψ excess.
- Detailed results for $\psi(2S)$.
- Detailed results for J/ψ elliptic flow (v_2).

Thank you for you attention